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DYNLET1
Model Formulation and User's Guide

compiled by *Mary A. Cialone*
Coastal Engineering Research Center

Michael Amein
Civil Analysis Group, Inc.

Prepared for Federal Highway Administration

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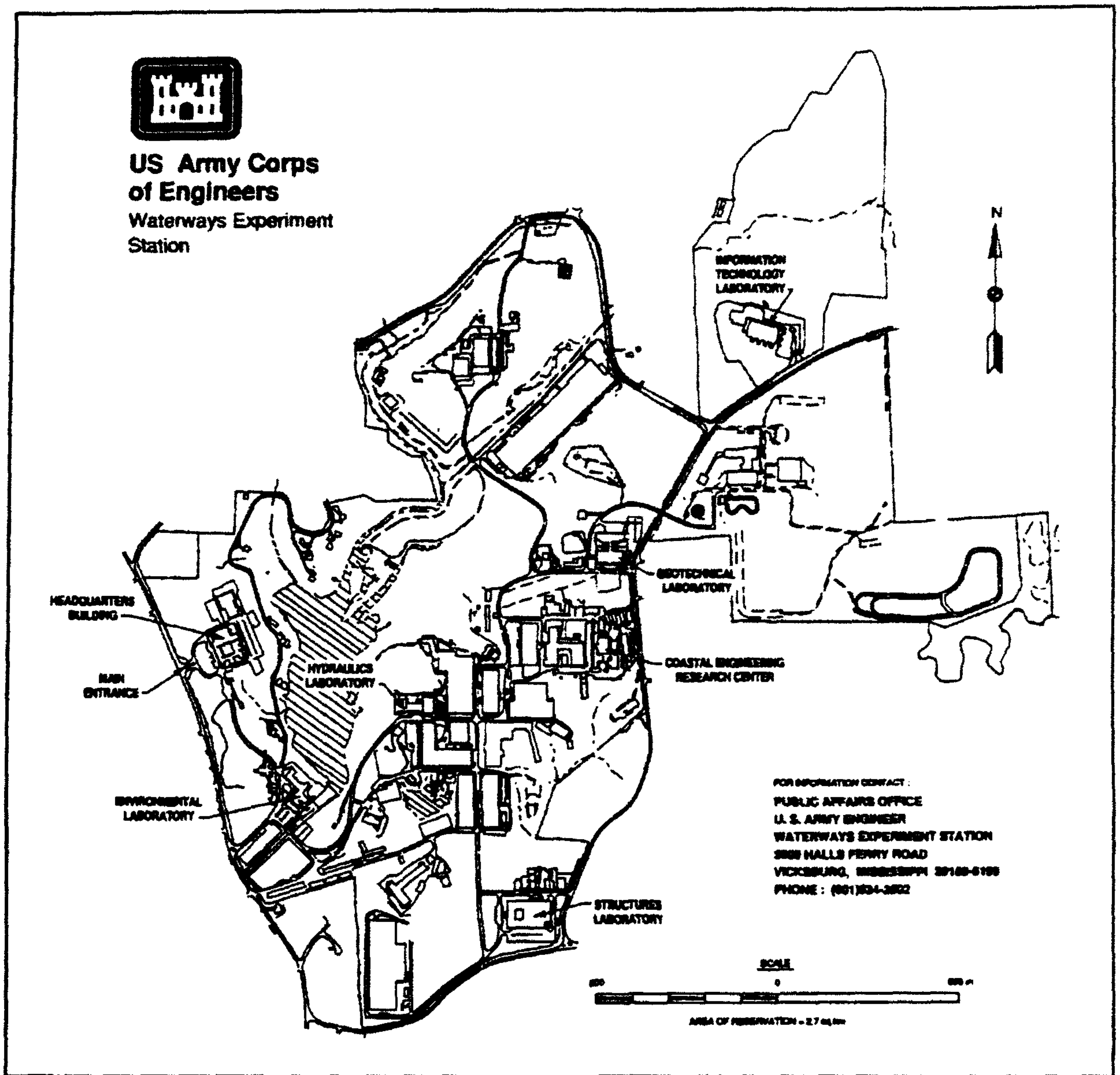

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Contents

List of Figures

Preface

The DYNLET1 numerical model was originally developed by Dr. Michael Amein, Civil Analysis Group, Inc., Raleigh, North Carolina, under contract to the U.S. Army Engineer Waterways Experiment Station (WES) Coastal Engineering Research Center (CERC). The model is capable of simulating one-dimensional (1-D) fluid flow from the ocean through a tidal inlet, into back bay regions, and up tributaries. An important feature of the model is the ability to represent an accurate flow distribution across any cross section, given the inherent limitations of a 1-D model.

This report documents the current version of the model and covers model theory and user guidance. The U.S. Department of Transportation (DOT) sponsored a study to apply DYNLET1 for the purpose of computing storm-induced velocities at project sites. Preparation and publication of this report were included in the DOT scope of work.

This work was performed under the direct supervision of Mr. Bruce Ebersole, Chief, Coastal Processes Branch, and Mr. H. L. Butler, Chief, Research Division, and under the general supervision of Dr. James R. Houston, Director, CERC, and Mr. Charles C. Calhoun, Jr., Assistant Director, CERC. At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI To SI Units Of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic feet per second	0.028317	cubic meters per second
feet	0.3048	meters
inches	25.4	millimeters

1 Introduction

The objectives of this manual are to introduce a state-of-the-art design-level model for predicting tide-dominated velocities and water level fluctuations at an inlet and interior back-bay system, and to provide detailed instruction in use of the model. The model solves the full one-dimensional (1-D) shallow-water equations employing an implicit finite-difference technique. The model is named DYNLET1, reflecting the fact that it is a 1-D model of the dynamic (time-dependent) behavior of the tidal flow at inlets.

DYNLET1 has a rigorous theoretical foundation, is numerically implemented in a sound manner, and is capable of describing realistic situations. It provides detailed velocity information across the inlet channels, is able to describe multi-channel inlets, and importantly, is easy to operate on a personal computer (PC). The model can be used for design-level studies for most inlets by providing reliable and accurate answers while requiring minimal modeling expertise, data entry, and numerical grid generation. For a more detailed description of model formulation, the user is directed to Amein and Kraus (1991).

Chapter 2 of this manual pertains to the theoretical basis of model DYNLET1, Chapter 3 covers input data requirements, Chapter 4 gives a detailed description of all input, output, and graphics files, and Chapter 5 describes how to use the editor and model. Appendices A-D present sample key input data files used in the application of DYNLET1 to Brunswick Harbor, Georgia.

2 Theoretical Background

DYNLET1 Terminology and Equation Notation

A system of five interconnecting channels meeting at two junctions is illustrated in Figure 1 to introduce DYNLET1 terminology and equation notation (Amein and Kraus 1991). The term "channel" is used in a broad sense to denote any body of water that conveys flow along its length regardless of its width. A short channel reach of length Δy with the flow from Section 1 to Section 2 is shown in Figure 2. The numbered dots in Figure 1, called "nodes," are the locations where channel cross sections are defined. A typical channel cross section is shown in Figure 3. The dots in Figure 3 are called "stations" and they define the geometry of the cross section. More complex systems may have more channels and junctions (locations where channels meet) than are shown in Figure 1.

In Figure 1, Nodes 1, 12, 20, and 26 are external nodes (nodes at which data are introduced to drive the model). Nodes 6, 7, and 13 are junction nodes at Junction 1, and Nodes 15, 16, and 21 are junction nodes at Junction 2. Junction nodes are coincident at the same geographical location. Channel 1 has six nodes beginning at the sea boundary at Node 1 and ending at Junction 1. An initial flow direction is assumed in defining the beginning and end of each channel for numbering or ordering of calculation nodes. Channel 2 has six nodes beginning at Node 7 at Junction 1 and ending at Node 12 in the bay. Channel 2 was terminated at Node 12 because a tide gauge was located at this node, making it convenient to use as an external boundary condition (a node at which data are introduced to drive the model). Node 7 becomes an internal boundary node because it defines the boundary of Channel 2, but is in the interior of the inlet system. The number of nodes of each channel, and their relationship to the junctions and boundary nodes, can be readily determined from a sketch such as Figure 1, which needs to be prepared based on physical features, particularly depth changes, changes in channel width, and inferred flow direction.

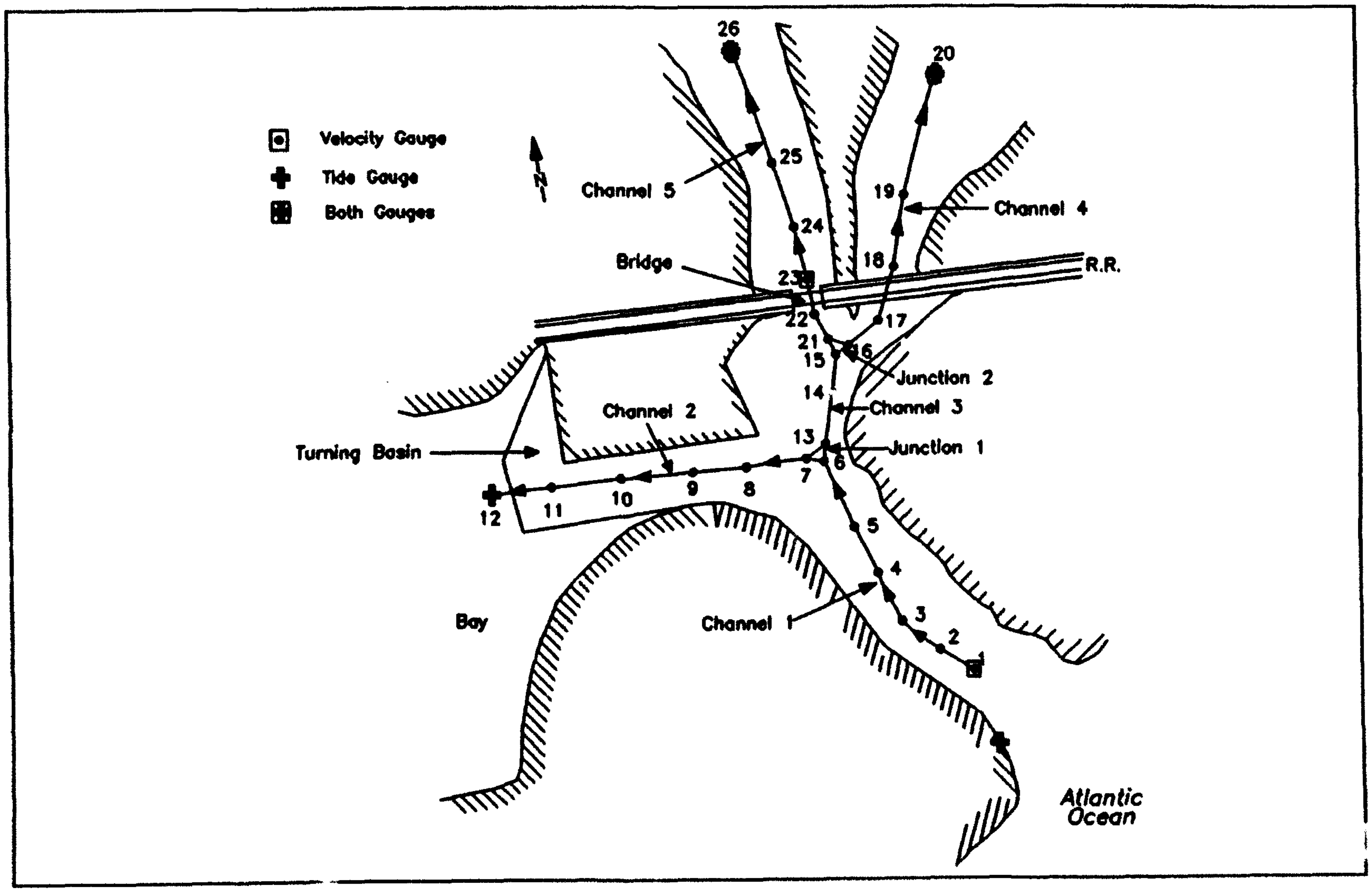

Figure 1. Definition sketch for inlet channel network (from Amein and Kraus (1991))

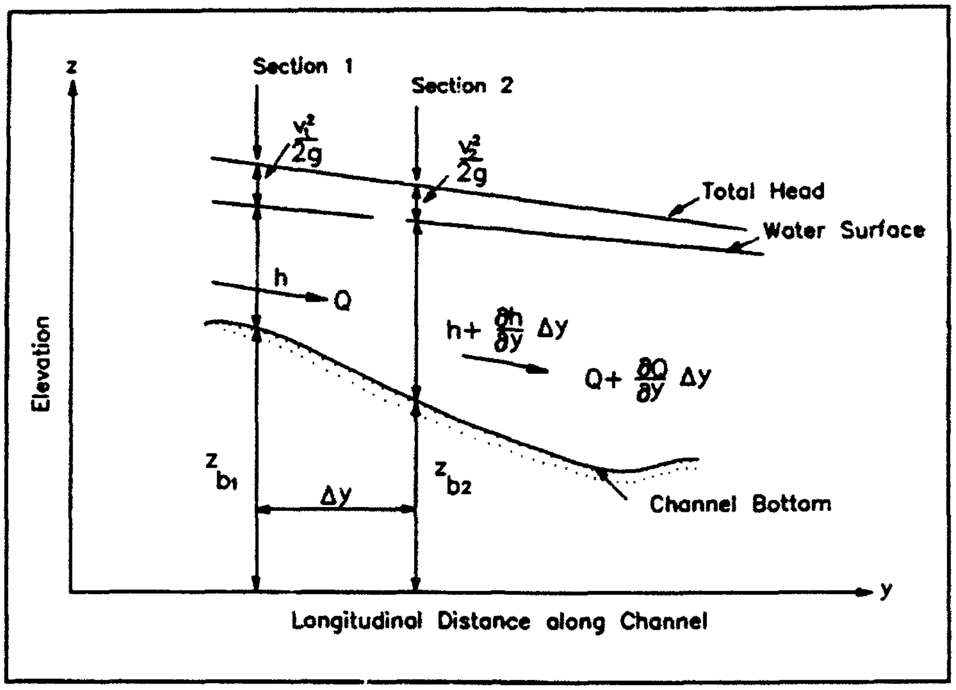

Figure 2. Definition sketch for inlet channel flow (from Amein and Kraus (1991))

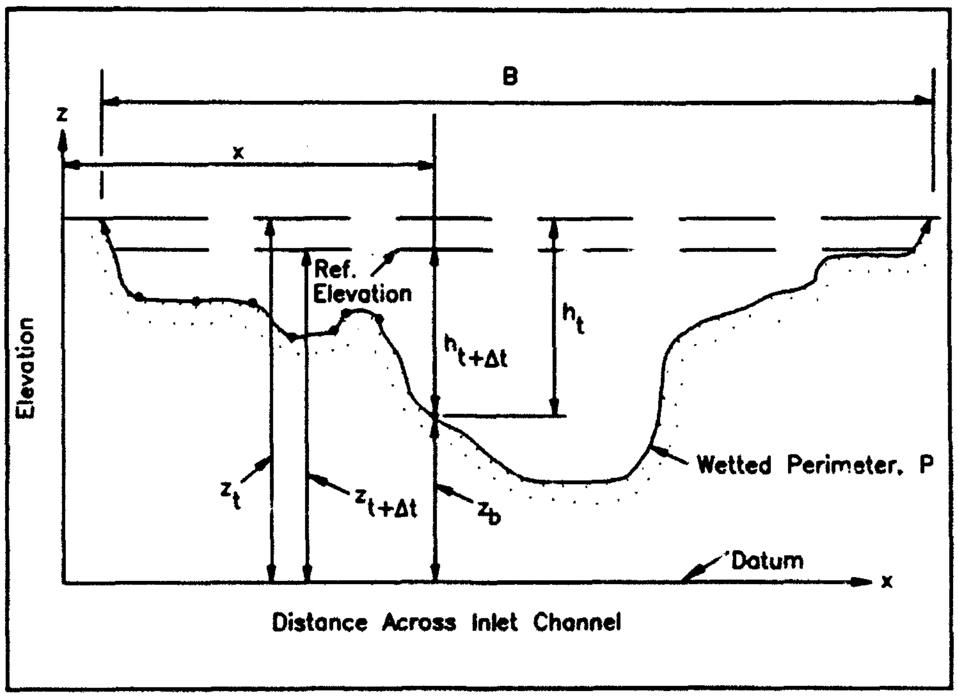

Figure 3. Definition sketch for inlet channel cross section (from Amein and Kraus (1991))

Basic Equations

The shallow-water hydrodynamic equations for 1-D depth-averaged flow consist of the equations for the conservation of mass, momentum, and energy (e.g., French (1985)). For most applications, the equations for conservation of momentum and energy produce identical results. For describing flow at tidal inlets, the momentum and mass equations may be written as

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial y}\left(\frac{Q^2}{A}\right) = - gAS_f + gB\tau_s - gAS_e - gA\frac{\partial z}{\partial y} \tag{1}$$

$$\frac{\partial Q}{\partial y} + \frac{\partial A}{\partial t} - q = 0 \tag{2}$$

where Q = volume flow rate, t = time, y = horizontal distance (along a channel), A = cross-sectional area, g = acceleration due to gravity, S_f = friction slope, B = width of top of channel cross section, τ_s = surface shear stress due to wind, S_e = transition loss rate with distance, z = water surface elevation, and q = lateral inflow or outflow per unit channel length per unit time.

Equations 1 and 2 are known as the 1-D shallow-water equations or the 1-D long-wave equations. The equations are valid if the assumption of a hydrostatic pressure distribution holds. They are applicable to tidal flow, flows in lakes and reservoirs, river flow, and wave motion where the wavelength is significantly greater than the water depth (hence the terminology "long-wave equations").

Equations 1 and 2 constitute a system of nonlinear first-order hyperbolic partial differential equations that must be solved numerically for arbitrary bathymetry and forcing conditions. The numerical scheme implemented in DYNLET1 extends and enhances the implicit finite-difference technique of Amein (1975) for solving the shallow-water wave equations. Features added specifically to address inlet flow and ease of use are: (a) variable bottom elevations and friction coefficients at user-specified *stations* across channel cross sections (*nodes*), (b) use of channel conveyance for describing friction loss, (c) computation of the velocity field at stations that can be spaced arbitrarily across each cross section (at each node), (d) optimization of the computational procedure by employing a banded matrix solver for channel networks, and (e) generalization of external and internal boundary conditions so that channel networks and multiple entrances can be described.

Numerical Solution Method

System of equations

The model determines values of flow properties at all specified nodes in each channel. With the flow rate Q and the water surface elevation z as the basic variables, each node has two unknowns, the values of Q and z. If there are N nodes in the inlet system, the total number of unknowns is $2N$; thus, $2N$ equations are needed to determine values of the basic unknowns. These equations are obtained from three sources:

a. The shallow-water wave equations at interior points of each channel.

b. The external boundary conditions.

c. The junction conditions.

It follows that a numerical model based on the 1-D shallow-water equations for a complex inlet consisting of interconnecting channels and bays requires three types of information:

a. Identification of interior points.

b. Specification of external boundary conditions.

c. Specification of junction conditions.

Interior points

Components of the numerical model involving interior points of channels are obtained by replacing partial derivatives in Equations 1 and 2 with finite differences. For a nonuniform rectangular spatial grid in the y - t plane, as specified by the user, distance along a channel is represented by abscissa, and time is represented by ordinate (Figure 4). The value of a function α and its derivatives at a point $M(i+1/2, j+\theta\Delta t)$ can be written as:

$$\alpha(M) = \frac{1}{2}[\alpha(i+1,j+1) + \alpha(i,j+1)]\theta + \frac{1}{2}[\alpha(i+1,j) + \alpha(i,j)](1-\theta) \tag{3}$$

$$\frac{\partial\alpha(M)}{\partial t} = \frac{1}{2\Delta t}[(\alpha(i+1,j+1) + \alpha(i,j+1)) - (\alpha(i+1,j) + \alpha(i,j))] \tag{4}$$

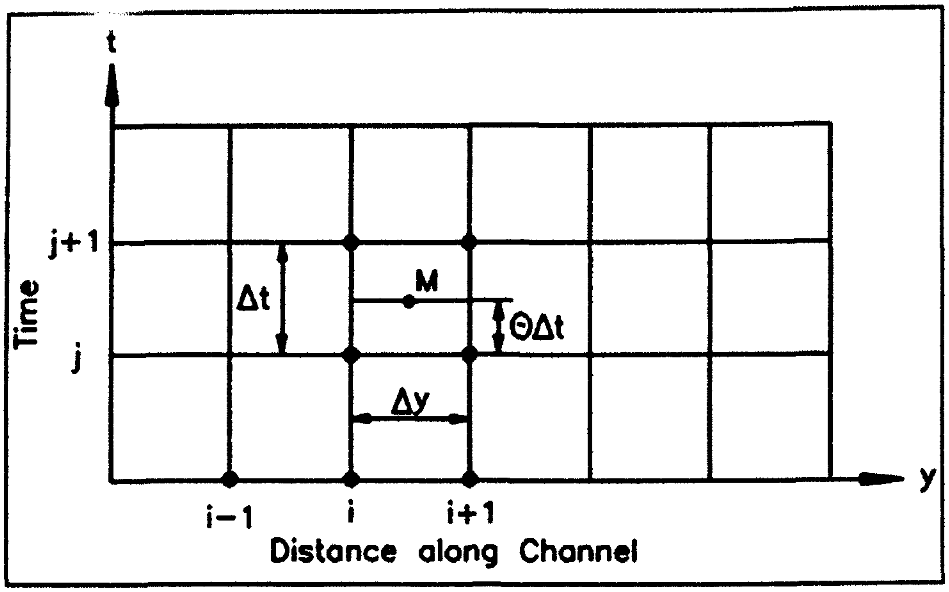

Figure 4. Computational grid on the *y-t* plane (from Amein and Kraus (1991))

and

$$\frac{\partial\alpha(M)}{\partial y} = \frac{1}{\Delta y}[\alpha(i{+}1,j{+}1) - \alpha(i,j{+}1)]\theta + \frac{1}{\Delta y}[\alpha(i{+}1,j) - \alpha(i,j)](1-\theta) \tag{5}$$

where θ is a weighting factor with a value between 0 (fully explicit scheme) and 1 (fully implicit scheme) that can be specified, and $\Delta y = y_{i+1} - y_i$ and $\Delta t = t_{j+1} - t_j$. In numerous applications and sensitivity tests, no significant difference in residual error occurred using either $\theta = 0.5$ or $\theta = 1$, in comparison to field data. However, using $\theta = 1$ reduces the number of iterations required. The weighting $\theta = 1$ is normally specified and is recommended as a starting value; this choice allows relatively large time-steps; for example, 1,800 sec, in typical applications.

At each point between sections i and $i+1$ and time-steps j and $j+1$, two algebraic equations are obtained. In networks consisting of interconnecting channels, each channel lacks two equations. These are provided by external boundary conditions where the channel meets the bay or the sea and by junction conditions where two or more channels meet.

Boundary conditions

Known water surface elevations or flow rates at external boundary points define boundary conditions. Variations of these boundary conditions are given by equations expressing discharge as a function of water surface elevation (as at a weir) or an analytical expression specifying water surface elevation or velocity as a function of time. A junction is created if two or more channels meet. A two-channel junction need not be specified, because two channels can be combined into a single channel. A three-node junction provides three equations for the inlet system through conservation of mass and continuity of the water surface. Similarly, a four-node junction provides four equations to the system.

Solution of the finite-difference equations

The finite-difference representations of the shallow-water equations, together with the boundary conditions and the junction conditions, constitute a system of $2N$ nonlinear algebraic equations in $2N$ unknowns, where N is the total number of nodes. In DYNLET1, the generalized Newton-Raphson iteration method is applied as the solution procedure. The equation system involves $2N$ unknowns, but each equation contains a maximum of four unknowns. Because the matrix is sparse, efficient methods of solution can be devised, as described by Amein and Kraus (1991). Iteration is continued until the differences in water surface elevation and discharge between successive iterations at any node fall below specified tolerance values. Tolerance values of 0.02 to 0.05 ft[1] (0.006 to 0.015 m) for elevations and 50 to 200 cu ft/sec (1.4 to 5.7 m^3/sec) for discharge are recommended for estimating tidal flows at most inlets, typically requiring three to five iterations for convergence.

Evaluation of shear stress terms

DYNLET1 implements Manning's formula for calculating the bottom shear stress. If a channel of complex shape, consisting of subareas with different roughnesses and depths, is divided into J elements ($J + 1$ station numbers), the volume flow rate is given by

$$Q = K\sqrt{S_f} \tag{6}$$

where

$$K = C\sum_{j=1}^{J}\frac{1}{n_j}A_j R_{h_j}^{2/3} \tag{7}$$

---

[1] A table of factors for converting non-SI units of measurement to SI units is presented on page vi.

In Equation 7, K is known as the conveyance, and A_j, R_{Nj}, and n_j are, respectively, the area, hydraulic radius, and resistance factor for element j. If a composite channel is divided into a number of nearly rectangular subchannels, the hydraulic radius of each subchannel would be nearly the same as the depth in the subchannel; therefore, the depth in a particular element is used as the hydraulic radius. Equation 7 also computes the flow rate and velocity in each subchannel, because the flow is proportional to the conveyance of the subchannel.

Evaluation of surface shear stress

The main source of surface shear stress is wind. The shear stress at the water surface due to the wind is computed using the turbulent shear stress formula given by Equation 8, where ρ_a is the density of air, C_D is the drag coefficient, and V_w is the component of wind speed along the channel.

$$\tau_s = \frac{C_D}{2} \rho_a V_w^2 \tag{8}$$

Evaluation of transition losses

Transition loss refers to the energy loss accompanying expansion or contraction of the flow area and may be expressed as Equation 9, where S_e is the rate of loss with longitudinal distance y, and K_e is an empirical drag coefficient:

$$S_{e_i} = \frac{K_{e_i}}{2g} \left| \left(\frac{Q_{i+1}^2}{A_{i+1}^2} - \frac{Q_i^2}{A_i^2} \right) \right| \tag{9}$$

3 Input Data Requirements

Coordinate System and Grid

An (x,y) coordinate system must be set up on a map of the area to identify the system geometry. The x-coordinate is used to identify positions across the channel cross section, and the y-coordinate is used to identify distances in the longitudinal direction; that is, in the direction of flow. The value of y along a channel increases from the beginning node to the end node, and the starting value of y is arbitrary. It is convenient for graphic displays, but not necessary, to measure distance from the sea boundary. Variable distances x and y are used to obtain realistic representation of the system; thus, closely spaced distances are used where significant changes take place in geometric properties.

From a knowledge of the flow system, the various channels comprising the system must be identified. If more than two channels meet or a channel branches out into two forks, then a junction must be identified. From a hydrographic map the locations of the channel cross sections can be determined. The distance between any two cross sections is arbitrary but cross sections should be placed at all locations where channel properties (width, depth, etc.) change significantly to represent the flow in regions of physical importance to the problem.

Cross Sections

Cross sections are identified at each node, a node being a grid point on the map representing the cross section passing through that grid point. Once the locations of the cross sections are known, then the number of nodes; that is, the number of cross sections comprising the inlet system, is defined.

For numbering of nodes, *an initial flow direction must be assumed* in order to determine where a channel begins and where it ends. *The selection of flow direction is arbitrary, but once it is chosen, it cannot be changed* during run time. It is convenient, although not necessary, to assume the initial direction of the flow to be from the sea toward land and to number the nodes in increasing order from sea to land.

A channel must have at least three nodes for hydrodynamic equations to be applied. The nodes in a given channel may be numbered starting from any arbitrary number, provided *there are no missing numbers, one of the channels starts from 1, the numbering is sequential*, and *the last node number is the same as the total number of nodes in the system*. Computation time can be minimized by selecting a numbering scheme that minimizes the difference between node numbers at junctions. This effort minimizes the matrix band width solved in the model.

Cross-section data provide information on the shape of the inlet and on the boundary roughness. The cross-section data consist of

a. Inlet geometry.

b. Bottom friction coefficients.

Inlet geometry

Once the locations of cross sections have been determined, geometric data for the cross section must be obtained from maps or field surveys. Data are recorded in English or SI units as "distances" and "elevations," where "distance" is an offset from the left bank, and "elevation" is the bottom elevation with respect to the reference elevation discussed earlier. The concepts of "distance" and "elevation" used here are the same as those used in the U.S. Army Engineer Hydrologic Engineering Center HEC-2 model (1984).

Bottom friction coefficient

Manning's coefficient of friction "n" is specified at every point on a cross section. These values are estimates obtained from previous studies, experience, and judgement. Textbooks such as Chow (1959) and publications by the U.S. Geological Survey and U.S. Army Corps of Engineers provide excellent guidelines for selecting values of n. A value of 0.02 is used for beach sand. This value may be increased to 0.025 if the boundary consists of coarse sand. If the inlet channel contains vegetation growth, then a value of 0.035 or higher is recommended. Values of the friction coefficient are specified at every data point in the cross section so that in a wide cross section consisting of part sandy bottom and part vegetation, different friction coefficients can be assigned to the sandy parts and the vegetated parts. The choice of Manning's n should not greatly affect model results. Generally a value of n in the range of 0.025 to 0.030 is used throughout the model domain as an initial estimate.

General Control Parameters

The general control parameters are values controlling the general operation of the program and consist of:

a. Initial time.

b. Termination time.

c. Computation time-step.

d. Number of iteration steps.

e. Weighting coefficient.

f. Tolerance values for iteration convergence.

g. External boundaries.

h. Internal boundaries.

i. Wind effects.

Brief descriptions of the general control parameters are given in the following:

Initial time

An initial time T0, conveniently the chronological time, in hours, must be specified.

Termination time

A termination time Tfin, also in hours, must be specified. The program stops when the termination time is reached.

Computation time-step

A computation time-step, in seconds, must be specified. A time-step of the same magnitude as the interval between external forcing function data inputs is generally satisfactory. Values of 900, 1,800, or 3,600 sec are suggested for normal tidal simulations. Storm simulations may require smaller steps (600-1,200 sec) because extreme velocities may occur. Accuracy in solution diminishes with increasing time-step; therefore, it is suggested that sensitivity of model accuracy to time-step size be investigated for each project application. Computation time is minimized by choosing the largest time-step that provides an accurate solution.

Number of iteration steps

The number of iteration steps needed for convergence is dependent on the tolerance values selected for the variables. For natural channels, convergence is usually attained in three to five iterations. Additional iterations may be required at start-up or where cross-sectional properties vary sharply between cross sections or there are rapid changes in water surface elevation and flow rate with time. A maximum of 20 iteration steps is recommended. If the solution does not converge within a reasonable number of iterations, one of the following situations may be prevalent: (1) the time-step may be too large for the problem, (2) the tolerance values may be too small for the given physical situation, (3) there may be errors in cross-sectional geometrical data, friction coefficients, or transition loss coefficients, or (4) the program may be failing because it is being applied to a physical situation not anticipated during program development.

Weighting coefficient

The weighting coefficient θ varies between 0.5 and 1.0. A weighting coefficient of 0.0 will transform the numerical procedure into an explicit method. However, the program has not been tested for weighting coefficients less than 0.5. Numerical experiments have shown that a value of θ equal to 1.0 may introduce some damping (however, it is usually negligible in tidal flows) and a value of θ equal to 0.5 may introduce spurious oscillations. An initial θ value of 1.0 is recommended; it is suggested to use 0.55 as a lower limit for θ.

Tolerance values for iteration convergence

The tolerance values for elevation (Zeps) and discharge (Qeps) determine the number of iterations required for the solution to converge. These values are dependent on inlet geometry. If the cross sections are highly irregular, the computations may not converge in a small number of steps or not at all if the tolerance values are too small. The program will stop and a message to this effect will be printed on the screen. If the tolerance values are large, the program will execute rapidly, but the accuracy of the solution is diminished. Tolerance values of 0.02 ft - 0.05 ft for elevation and 50 cfs to 200 cfs for discharge are reasonable estimates for most inlets. If the solution does not converge, it is recommended that a large value for Qeps, say 4,000 cfs in English units, be selected. The most likely cause of lack of convergence is input data error.

External boundaries

The external boundary type and the boundary forcing data must be identified. Currently the program accepts three types of external boundaries:

a. **Type 1.** Values of water surface elevation as a function of time are tabulated in the input file. If more than one Type 1 boundary is defined, the user must ensure that tabulated time series begin at the same elevation value.

b. **Type 2.** Values of discharge as a function of time are tabulated in the input file.

c. **Type 7.** The water surface elevation as a function of time is described by a formula, e.g., a sine wave. A sine wave requires two parameters, wave amplitude and period.

For every external boundary node, a tabulation of time-dependent input data is needed. The tabulated values are ignored if the boundary type is 7; that is, if a formula describes the water surface elevation as a function of time. For boundary types 1 and 2, values of water surface elevation and discharge as functions of time must be tabulated. In boundary type 7, values of wave amplitude and period are given as desc1 and desc2.

Internal boundaries

Internal boundaries are specified at junctions; however, DYNLET1 handles this automatically. The program determines how junction nodes are located with respect to the channels, and applies the conservation of mass and energy at the junction nodes.

Wind effects

Inclusion of wind effects on the flow is controlled by a wind index parameter. A value of 0 for the wind index parameter indicates that the simulation does not include wind effects. A value of 1 indicates the inclusion of wind effects and the program requires a coefficient of wind drag to be used in the calculation of surface shear as an additional input value. Typically a wind drag coefficient value of 6.0×10^{-6} is suggested.

Nodal Parameters

The nodal parameters are values of variables assigned to an entire channel cross section and consist of:

a. Node distance.

b. Graphical position.

c. Reference elevation.

d. Lateral inflow rate.

e. Channel alignment angle.

f. Transition loss coefficients.

g. Initial values of water surface elevation.

h. Initial values of volume flow rate.

Node distance and graphical position

The position of each node is defined as both a relative distance (y) from the first node and a graphical position from an arbitrary origin (Figure 5). The node distance is the cumulative distance along the channel to each node. The graphical position defines the left channel bank location for plotting purposes only. The x-y coordinate system in Figure 5 is a global x-y system for positioning and graphically displaying each node and has no computational significance.

Reference elevation

The reference elevation is the datum for specifying water surface elevation and channel geometry. Mean sea level, mean low water, or any other suitable horizontal datum can be chosen as the reference elevation. If mean sea level is selected as the reference elevation, the water surface elevation z would be the difference in elevation between the water surface and mean sea level. For tidal inlets, mean low water or mean sea level is recommended as the reference elevation.

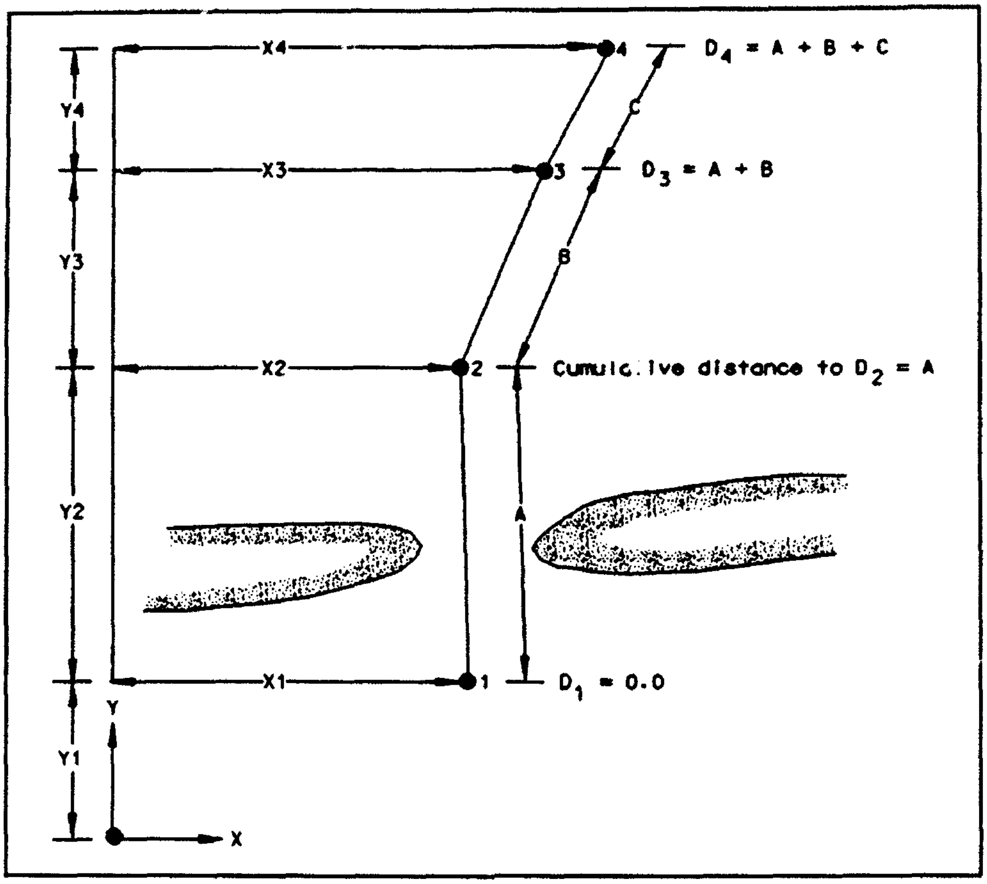

Figure 5. Node distance and graphical position

Lateral inflow rate

The lateral inflow rate is the rate at which water enters or leaves the channel at a cross section from the channel banks or bottom by seepage, or enters or leaves the water surface by evaporation or precipitation. Flow from a minor tributary stream can be represented by specifying values for lateral inflow. An examination of the flow records at the two ends of a channel reach can be used to evaluate lateral inflow rate. The lateral inflow rate is usually neglected in tidal inlets.

Channel alignment angles

The channel alignment angle is defined as the angle that the channel axis makes with a reference axis. The reference axis may be the bottom edge of the map. The angle is measured counterclockwise from the reference axis, and is given in degrees. Values of channel alignment angle must be specified at each node. This angle is used for properly applying wind stress and for plan-view plotting and can be ignored if these factors are not operative.

Transition loss coefficients

The transition loss coefficient accounts for turbulent losses due to flow expansion and contraction and must be specified at all nodes. If these losses are ignored, then they must be set to zero. These losses become important in the accurate representation of turbulent losses through sudden contractions, expansions, bridges, culverts, etc. It is to be noted that a given cross section that causes flow contraction during ebb flow will cause flow expansion during flood flow; therefore, a composite coefficient is used. A value of 0.5 for the composite coefficient is recommended as an initial estimate. For important structures, such as bridges, it is desirable to calibrate this coefficient with field data.

Initial values of water surface elevation

Initial values of water surface elevation obtained from field measurements must be given at every node. It is suggested that each simulation begin assuming zero flow throughout the model domain with a horizontal water surface at an elevation consistent with the initial value in the boundary condition time series. This is known as a "cold start."

Initial values of volume flow rate

Initial values of volume flow rates must be specified at all nodes. These values are taken from field measurements. For a cold start, the initial values of discharge may be set to zero and the forcing time series at external boundaries should begin at zero and gradually build up to the appropriate time series. Starting the system from rest avoids "shocking" the system.

4 Description of Input, Output, and Graphics Files

DYNLET1 uses three required input files: START.DAT, SECTION.DAT, EXTER.DAT, and one optional file: PARAM.DAT. PARAM.DAT is needed only if plotting output of velocity and stage as functions of time at selected locations is desired. Example input files for Brunswick Harbor, Georgia, are shown in Appendices A through D and a grid network for Brunswick Harbor is shown in Figure 6. In this section, the contents of all input, output, and graphics files are discussed. Program EDINLET is recommended for creating all DYNLET1 input files. EDINLET is a menu-driven file editor that guides the user in creating each input file. This program will be discussed in Chapter 5.

START.DAT File

Up to 100 comment lines can be inserted at the beginning of the file. Comment lines are identified by an asterisk in Column 1. Titles, identifications, notes, and miscellaneous useful information can be entered in this area.

The START.DAT file consists of four data groups containing similar input information. Group A is General Parameters, Group B is Channel and Junction Parameters, Group C is Computation Parameters, and Group D is Node Parameters. Each data group consists of several subgroups of input data. Each subgroup consists of a single title line; for example:

<u>B.1</u> # Channels # Junctions # Boundary Nodes

followed by one or more lines of data. As many lines of data as needed may be used. <u>All data are input in free format</u> and there is no requirement as to how many items can be put on a line.

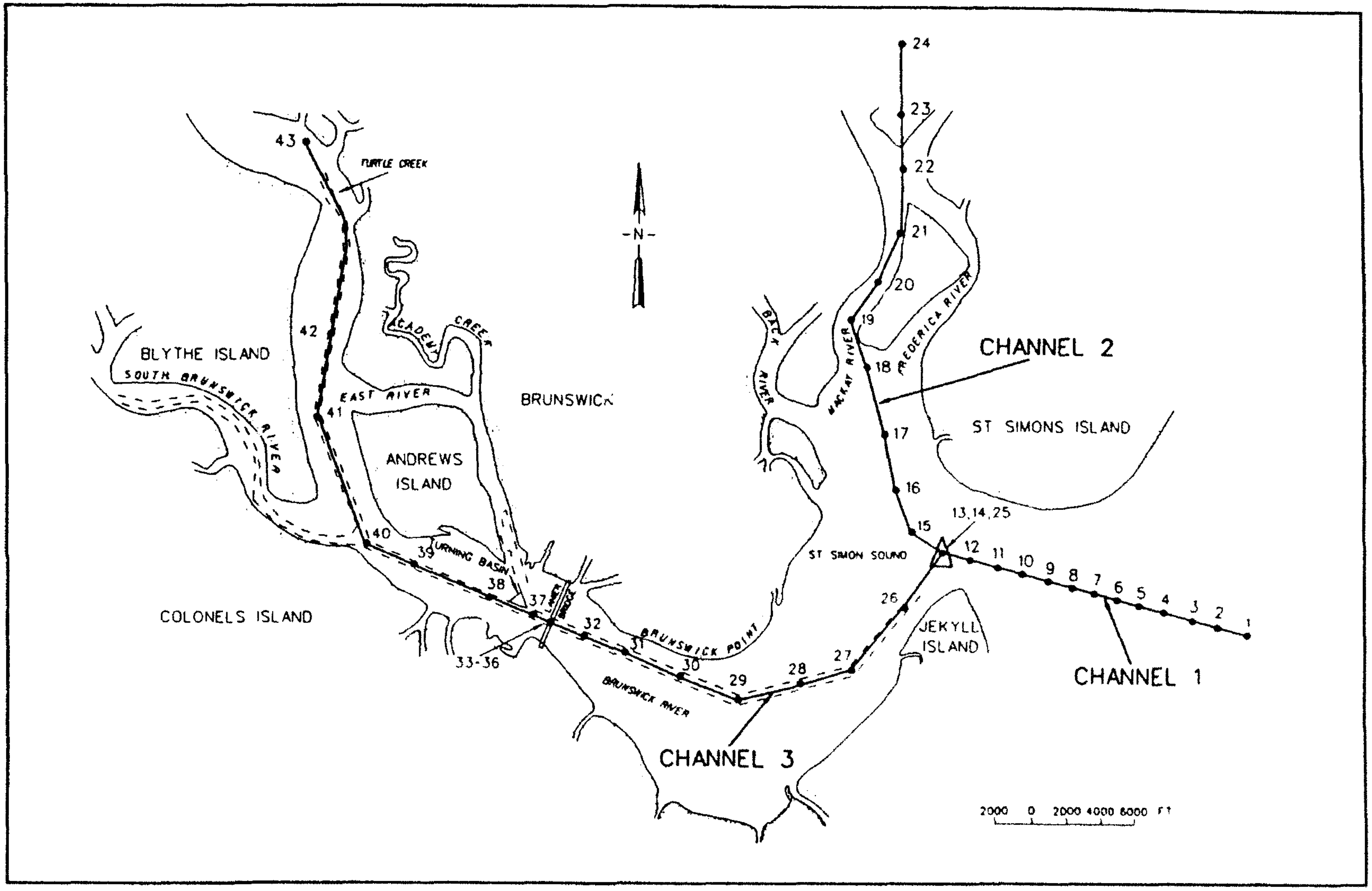

Figure 6. Brunswick Harbor, Georgia, grid network

Group A: **General Parameters**

A.1: General input: (T0 Tfin Zeps Qeps Theta N Iwind)

T0: Simulation start time
Tfin: Simulation end time
Zeps: Tolerance value for elevation to determine solution convergence
Qeps: Tolerance value for discharge to determine solution convergence
Theta: Weighting coefficient
N: Number of nodes
Iwind: Index to indicate inclusion of wind effects

A.2: System units: (units)

units: System of units (ENGLISH or SI)

A.3: Length units (unitl)

unitl: Distance units (feet, miles, meters, or kilometers)

Group B: **Channel and junction parameters and external boundary information**

B.1: Number of channels, junctions, and external boundary nodes (NC NJ NBP)

NC: Number of channels
NJ: Number of junctions
NBP: Number of external boundary points

B.2: Channel number, and starting and ending nodes (IC IBEGIN(IC) IEND(IC))

IC: Channel number
IBEGIN(IC): Starting node of channel
IEND(IC): Ending node of channel

B.3: Junction number, number of nodes in junction, nodes (I Nd(I) Ndn(k),k=1,Nd(I))

I: Junction number
Nd(I): Number of nodes in the junction
Ndn(I): Node numbers at junction

B.4: External boundary number, node number, boundary type (IBP NDB(IBP) Id(IBP) desc1IBP) desc2(IBP))

IBP: External boundary number (index)
NDB(IBP): Node number
Id(IBP): Boundary type
desc1(IBP): First identifier (if applicable)
desc2(IBP): Second identifier (if applicable)

Group C: **Computational Parameters**

C.1: Computational time-step in seconds (DTCOM)
DTCOM: Time-step
C.2: Maximum number of iterations (Itern)
Itern: Maximum number of iterations
C.3: # of printout times (NP)
NP: Number of printout (display) times desired
C.4: Printout times (NPR)
NPR( ): Printout times (in hours)
C.5: # of output nodes (NoutN)
NoutN: Number of nodes at which output is desired
C.6: Output nodes (Nout)
Nout( ): Output nodes

Group D: **Nodal parameters**

D.1: Node distances (Dist)
Dist( ): Cumulative distance along channel to each node
D.2: X coordinate (Xbank)
Xbank( ): X coordinate of left bank at each node
D.3: Y coordinate (Ybank)
Ybank( ): Y coordinate of left bank at each node
D.4: Lateral inflow (QL)
QL( ): Values of lateral inflow rate each node
D.5: Reference elevations (Zb)
Zb( ): Values of reference elevation at each node
D.6: Channel alignment angles (PHI)
PHI( ): Values of channel alignment angles at each node
D.7: Transition loss coefficients (KE)
KE: Transition loss coefficient values at each node
D.8: Initial water level (ZIN)
ZIN( ): Initial water surface elevation values at each node
D.9: Initial discharge (QIN)
QIN( ): Initial discharge values at each node
D.10: Wind stress coefficient (WS)
WS: Value of wind stress coefficient if IWIND=1

SECTION.DAT File

This file contains detailed information on cross-sectional geometry and boundary resistance. Cross-section geometry is defined by data points identifying the channel boundary, and each data point is described by pairs of values of "distance" and "elevation." The boundary resistance is defined by a value of the coefficient of friction at each data point. The input data format is described in the following:

Group E: **Cross-section parameters**

E.1: Cross-section (node) number and number of elevation points (I NumElevs(I))

I:	Node Number
NumElevs(I):	Number of elevation points in the cross section

E.2: Stations and elevations (stat, elev)

stat(I):	Distance from left bank to each point on the cross section
elev(I):	Elevation of each point on the cross section

E.3: Manning's coefficient at each station (ne)

ne(I):	Manning's coefficient of friction

Note. E.1, E.2, and E.3 are needed for each node (cross section); therefore, the total number of Group E's is equal to the number of nodes. The record order is E.1, E.2, E.3 for the first node, E.1, E.2, E.3 for the second node, and so forth.

EXTER.DAT File

This file contains time-dependent boundary data (either elevation or discharge). Time-dependent data at each external boundary node are tabulated as a function of time. Details of data requirements are described as follows.

Group F: **Time-dependent data**

F.1: Index, time, and external boundary values (I, Time, Ust)

I:	Index (counter)
Time(I):	Time in hours
Ust (1,L):	Boundary value at boundary point 1 at time L
Ust (2,L):	Boundary value at boundary point 2 at time L
Ust (3,L):	Boundary value at boundary point 3 at time L
	.
	.
Ust(NBP,L):	Boundary value at last boundary point at time L

PARAM.DAT File

This file specifies nodes and stations for output of velocity and stage for display on a computer terminal and/or a printer. Graphics programs HPLOT and VPLOT (described in the Graphics portion of this section) can be used to plot data at the specified nodes.

Group G: **Velocity output**

G.1: Number of nodes where velocity plots are desired (VoutN)
VoutN: Number of nodes where velocity plots are desired
G.2: Node number for velocity plot (VelNode)
VelNode(I): Node number
G.3: Number of velocity output stations at this cross section (node) (NumStations)
NumStations(I): Number of stations at this node for velocity plots
G.4: Velocity stations (VelStations)
VelStations(I): Identification of the stations at node I

Note: Sets G2 through G4 are repeated VoutN times.

Group H: **Stage (water surface elevation) output**

H.1: Number of nodes at which stage plots are desired (EoutN)
EoutN: Number of nodes at which stage plots are desired
H.2: Identification of desired nodes (ElNode)
ElNode(I): Node number

Note: The simplest method for generating a PARAM.DAT file is by running EDINLET as described in Chapter 5.

OUTPUT Files

DYNLET1 generates two output files: INLET.OUT and CHANNEL.DAT. The file INLET.OUT contains computed values of volume flow rate, water surface elevation, and average velocity at the designated nodes and times specified in the START.DAT file.

CHANNEL.DAT contains an echo of the input records, including values of stations, elevations, and friction factors at all nodes. This is followed by computed values of discharge and water surface elevation at all nodes at the specified output times. CHANNEL.DAT is used as an independent source file for generating graphs. The graphics program CHANNEL uses CHANNEL.DAT to generate plots of channel cross sections and water surface elevations at all nodes at all specified times. In addition to CHANNEL.DAT, the file PARAM.DAT is needed to generate plots of velocity (VPLOT) and stage (HPLOT) at specified locations.

GRAPHICS Files

Channel

Program CHANNEL determines velocities and water surface elevation across the channel, and displays these data on a computer screen, along with the channel cross sections for every node for each specified output time.

VPLOT

Program VPLOT creates plots of velocity as a function of time at all locations specified in PARAM.DAT.

HPLOT

Program HPLOT produces plots of water surface elevation as a function of time at the locations specified in PARAM.DAT.

Each of the graphics programs prompts the user for a response in order to display the next plot or exit the program. Plots are displayed sequentially by pressing enter and the program is terminated by pressing the escape key.

5 Using EDINLET and DYNLET1

Installation

All files needed to run EDINLET and DYNLET1 are supplied on a high-density 3.5-in. diskette. Although DYNLET1 can be run from the diskette for small projects, installation on a hard disk using the following procedure is recommended:

a. Create a subdirectory on the hard disk: <u>MD C:\DYNLET</u>

b. Assuming the diskette is in the A: drive, copy all the files to the DYNLET subdirectory from any directory on the hard disk:

<u>COPY A:*.* C:\DYNLET</u>

Creating Input Files with EDINLET

Although the user can create the three required input files using a text editor and following the guidelines given in Chapter 4 on INPUT FILES, it is recommended that program EDINLET be used for creating all input files. EDINLET enables the user to easily create all required input files and is initiated by typing:

EDINLET

at the DOS prompt. The following screen is then displayed:

DYNLET1 EDITOR

NUMERICAL MODEL FOR INLET DYNAMICS

Michael Amein
Civil Analysis Group, Inc.
7424 Chapel Hill Road, Raleigh, NC 27607
(919)-851-1455

Pressing **RETURN** displays the "Running EDINLET" screen as follows:

RUNNING EDINLET

Editing Existing Files

Generating New Input Files

Assuming input files were not developed previously, at this screen the user should press the right arrow key to highlight the "Generating New Input Files" box and then press **ENTER**. The main selection screen for creating and editing input data is then displayed as follows:

Inlet Dynamics Data Editor	
Edit Computational Parameters	Edit Node Parameters
Edit Channel Descriptions	Edit Junction Descriptions
Edit Boundary Point Descriptions	Designate Output Stations
Designate Output Times	Edit Comment Section
Edit Cross-Section Data	Edit Time-Dependent Data
Edit Existing Data File	Save Data in Memory to File
Create Param.dat File	
Use arrow keys, **ENTER** to select, Alt-X to quit	

The user should begin by highlighting "Edit Computational Parameters" and pressing **ENTER**. These input data define the overall problem and should be entered prior to any other input data. Values entered in the "Computational Parameters" screen include the number of nodes, channels, junctions, and boundary points for the specific project, as well as the start time, end time, time-step, system units, tolerance values, iteration limit, weighting factor and inclusion of wind effects. Proceeding down the main selection screen to "Edit Channel Descriptions" allows the user to input the starting and ending nodes for each channel. The "Edit Boundary Point Descriptions" selection is for entering the external boundary nodes and the external boundary type. Selection of "Designate Output Times" allows the user to select the hours when output data should be saved. The "Edit Cross Section Data" selection is used to input the distance and elevation pairs describing each cross section as well as friction coefficients for each point on the cross section. "Edit Existing Data File" is used to load files START.DAT, SECTION.DAT, and/or EXTER.DAT that exist on the user's directory. This is used only if the files already exist in the user's directory and further editing of the files is needed. PARAM.DAT is created only when plots of velocity and stage are desired. To generate a PARAM.DAT file, the user highlights "Create Param.dat File" and presses **ENTER**. The user can then select nodes and stations for velocity plots, and nodes for water elevation plots. "Edit Node Parameters" is used to enter all of the information in Group D of the START.DAT file (channel distances, x-coordinates, y-coordinates, reference elevations, alignment angles, transition loss coefficients, initial water levels, and initial discharge values). The "Edit Junction Descriptions" selection is used to enter the node numbers at each junction. Selection of "Designate Output Stations" allows the user to select locations where data should be saved. "Edit Comment Section" is used to type in titles, dates, labels, and notes pertinent to the user's project. Selection of "Edit Time-Dependent Data" allows the user to enter boundary forcing data (time, water surface level, and/or velocity). "Save data in memory to file" will generate the necessary DYNLET1 input files from the information inserted during the editing session. EDINLET generates START.DAT, SECTION.DAT, and EXTER.DAT files required by DYNLET1 as well as PARAM.DAT when it is applicable.

Editing Existing Files

EDINLET can be very effective for editing and error checking of existing files. To edit existing files, the files must have the extension .DAT. Therefore all data files having identifying extensions other than .DAT must be copied to files with extension .DAT.

After initiating EDINLET and reaching the "RUNNING EDINLET" screen, move the cursor to highlight "Editing Existing Files," and press the ENTER key. The START.DAT, SECTION.DAT, and EXTER.DAT files will be loaded into computer memory by pressing the enter key three times. From then on, the procedure for editing existing files is the same as was explained in the section that begins on page 25 titled "Creating Input Files with EDINLET."

Running DYNLET1

DYNLET1 is initiated at the DOS prompt by typing:

DYNLET1

The program responds with the following banner:

```
                    DYNLET1
     DYNLET1: DYNAMIC IMPLICIT NUMERICAL
      MODEL OF ONE-DIMENSIONAL TIDAL
           FLOW THROUGH INLETS

                     by

       Michael Amein and Nicholas C. Kraus
          919-851-1455   601-634-2018
          Raleigh, NC  Vicksburg, MS

        TECH REPT CERC-91-10, Sept 1991

    Number of Nodes: dynamic allocation using C
     may be up to 150 nodes under DOS on PCs
             Current version assumes

  Maximum number of channels:  15
  Maximum number of junctions:  10
  Maximum number of external boundary points:  10
  Number of nodes at junction fixed at 3
  Maximum number of stations in a cross section:  45

The above parameters can be varied, but will require
modification of the source code

Please remove TSR's to make maximum free memory

MODELING INLET DYNAMICS

ENGLISH convert=1.00  G=32.2
```

As the program is running, the simulation time is displayed on the PC screen and the total run time is displayed upon completion of the simulation. Model results in output files INLET.OUT and CHANNEL.DAT can then be examined and analyzed. Graphical output can be produced using the programs CHANNEL, HPLOT, and VPLOT as discussed in Chapter 4.

References

Amein, M. (1975). "Computation of flow through Masonboro Inlet, North Carolina," *Journal of Waterways, Harbors, and Coastal Engineering Division* 1 (WW1), 93-108.

Amein, M., and Kraus, N. C. (1991). "DYNLET1: Dynamic implicit numerical model of one-dimensional tidal flow through inlets," Technical Report CERC 91-10, U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Vicksburg, MS.

Chow, V. T. (1959). *Open channel hydraulics*. McGraw-Hill, Inc., New York.

French, R. H. (1985). *Open channel flow*. McGraw-Hill Inc., New York.

U.S. Army Engineer Hydrologic Engineering Center. (1984). "HEC-2 water surface profiles user's manual," U.S. Army Engineer Hydrologic Engineering Center, Davis, CA.

Appendix A
START.DAT File

```
* * * * * * * * * * * * * Brunswick Harbor
* * * * * * * * * * * * * Georgia
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
**************************************************
* START.DAT created on 01/04/1993 at 18:33.
**************************************************
A  General Parameters
**************************************************
A.1 T0     Tfin     yeps     Qeps     theta    N    IWIND
     6.00   21.00    0.05    200.00    1.00    43     0
A.2 Units
ENGLISH
A.3 Unit of Distance
FEET
**************************************************
B   Channels, Junctions and External Boundary Nodes
**************************************************
B.1 # Channels, # Junctions, # Boundary Nodes
        3         1          3
```

B.2 Channel Descriptions Channel No. Start End

1	1	13
2	14	24
3	25	43

B.3 Junction Number Nodes

1	3	13	14	25

B.4 Boundary Point Node ID Parameters

1	1	1
2	24	2
3	43	2

****

C Computational Parameters

****

C.1 Computation time step in seconds
1800.00

C.2 Maximum Iterations per time step
10

C.3 Number of printout times
16

C.4 Print times in hours

6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00
14.00	15.00	16.0	17.0	18.0	19.00	20.0	21.0

C.5 Number of output stations
43

C.6 Output Stations

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40
41	42	43					

****

D Node Parameters

****

D.1 Node Distances

0.0	7333.0	16166.0	20433.0	25433.0	29933.0
34600.0	39433.0	43933.0	46433.0	48933.0	51933.0
55600.0	55600.0	59933.0	62433.0	64933.0	67433.0
70100.0	72600.0	75600.0	80600.0	85933.0	100000.0
55600.0	60600.0	65767.0	70767.0	73267.0	75767.0
80767.0	83267.0	84533.0	84733.0	84833.0	85033.0
86033.0	88543.0	91043.0	93867.0	101710.0	106700.0
121000.0					

D.2 X Coordinates

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

D.3 Y Coordinates

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

D.4 Lateral Inflow

0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0					

D.5 Reference Elevations

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

D.6 Channel Alignment Angles

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

D.7 Transition Loss Coefficients

0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00					

D.8 Initial Water Level

5.0	5.0	5.0	5.0	5.0	5.0
5.0	5.0	5.0	5.0	5.0	5.0
5.0	5.0	5.0	5.0	5.0	5.0
5.0	5.0	5.0	5.0	5.0	5.0
5.0	5.0	5.0	5.0	5.0	5.0
5.0	5.0	5.0	5.0	5.0	5.0
5.0	5.0	5.0	5.0	5.0	5.0
5.0					

D.9 Initial Discharge

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

Appendix B
SECTION.DAT File

```
**************************************************
E    Cross Section Geometry and Friction Coeffs
**************************************************
E.1  Node    Number of Elev Pts
      1        11
E.2  Stations and Elevations
        0.00    -24.00   3333.30    -25.00   6666.70    -26.00
    10000.00    -27.00  13333.30    -29.00  16666.70    -29.00
    18333.30    -30.00  20000.00    -32.00  21666.60    -30.00
    22500.00    -29.00  23333.30    -30.00
E.3  Mannings Coefficient at each station
        0.0250   0.0250   0.0250   0.0250   0.0250   0.0250
        0.0250   0.0250   0.0250   0.0250   0.0250
E.1  Node    Number of Elev Pts
      2        16
E.2  Stations and Elevations
        0.00    -22.00   3333.30    -23.00   6666.70    -23.00
    10000.00    -29.00  13333.30    -30.00  15333.30    -32.00
    16666.70    -32.00  19000.00    -33.00  21333.30    -34.00
    23333.30    -33.00  26666.60    -28.00  28666.60    -30.00
    31000.00    -31.00  36666.60    -36.00  37333.30    -35.00
    39000.00    -30.00
E.3  Mannings Coefficient at each station
        0.0250   0.0250   0.0250   0.0250   0.0250   0.0250
        0.0250   0.0250   0.0250   0.0250   0.0250   0.0250
        0.0250   0.0250   0.0250   0.0250
E.1  Node    Number of Elev Pts
      3        17
```

E.2 Stations and Elevations

0.00	-16.00	6666.70	-16.00	10000.00	-15.00
13333.30	-19.00	16666.70	-32.00	17333.30	-18.00
18333.30	-17.00	20000.00	-18.00	23333.30	-26.00
25000.00	-29.00	26333.30	-30.00	27666.60	-32.00
29166.60	-30.00	32166.60	-32.00	34500.00	-30.00
36666.60	-29.00	38333.30	-28.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	

E.1 Node Number of Elev Pts

4 19

E.2 Stations and Elevations

0.00	-10.00	4000.00	-10.00	5000.00	-14.00
6666.70	-15.00	9000.00	-12.00	9666.70	-6.00
11666.70	-9.00	13333.30	-12.00	13833.30	-18.00
15000.00	-21.00	16666.70	-32.00	18333.30	-12.00
20000.00	-12.00	22166.60	-18.00	23333.30	-21.00
26666.60	-26.00	28333.30	-29.00	33333.30	-30.00
37666.60	-28.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts

5 24

E.2 Stations and Elevations

0.00	-5.00	333.30	-6.00	1666.70	-10.00
4000.00	-12.00	5000.00	-15.00	6666.70	-12.00
9333.30	-14.00	11666.70	-7.00	13500.00	-12.00
14333.30	-14.00	15333.30	-12.00	16666.70	-32.00
17000.00	-18.00	17166.60	-12.00	17400.00	-6.00
17833.30	-3.00	18166.60	-6.00	19333.30	-10.00
21000.00	-12.00	22166.60	-15.00	24000.00	-18.00
25333.30	-21.00	29333.30	-24.00	36666.60	-24.00

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250

E.1 Node Number of Elev Pts

6 22

E.2 Stations and Elevations

0.00	-7.00	1666.70	-12.00	3333.30	-6.00
4666.70	-6.00	5333.30	-7.00	6000.00	-6.00
6666.70	-7.00	8666.70	-12.00	12666.70	-12.00
14000.00	-13.00	15000.00	-15.00	16166.70	-18.00
16666.70	-32.00	17333.30	-18.00	17666.60	-12.00
18833.30	-6.00	20000.00	-6.00	21000.00	-12.00
23666.60	-18.00	27333.30	-20.00	30000.00	-19.00
34666.60	-20.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

7 30

E.2 Stations and Elevations

0.00	-3.00	3333.30	-6.00	3833.30	-8.00
9333.30	-10.00	12666.70	-8.00	13333.30	-12.00
15333.30	-16.00	16066.70	-18.00	16666.70	-32.00
17000.00	-30.00	17033.30	-24.00	17066.60	-18.00
17100.00	-12.00	17133.30	-6.00	17333.30	-4.00
17833.30	-6.00	18333.30	-8.00	19333.30	-6.00
20000.00	-6.00	21266.60	-8.00	21666.60	-5.00
22166.60	-4.00	22500.00	-4.00	24000.00	-12.00
25000.00	-13.00	26666.60	-16.00	29333.30	-15.00
33333.30	-13.00	35000.00	-13.00	38333.30	-12.00

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250

E.1 Node Number of Elev Pts

8 26

E.2 Stations and Elevations

0.00	-5.00	6666.70	-5.00	7000.00	-6.00
8333.30	-11.00	10000.00	-6.00	10833.30	-5.00
11666.70	-6.00	13666.70	-12.00	16000.00	-18.00
16666.70	-32.00	17066.60	-30.00	17800.00	-24.00
17866.60	-18.00	17933.30	-6.00	18000.00	-1.00
20333.30	-3.00	21333.30	-10.00	21833.30	-3.00
22166.60	-6.00	23000.00	-10.00	24000.00	-6.00
25000.00	-3.00	27000.00	-12.00	28333.30	-15.00
29666.60	-12.00	33333.30	-10.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

9 37

E.2 Stations and Elevations

0.00	4.00	3333.30	0.00	3666.70	-0.50
4666.70	-4.00	7000.00	-7.00	9166.70	-5.00
12000.00	-6.00	13000.00	-6.00	14333.30	-5.00
16000.00	-6.00	17000.00	-10.00	18000.00	-12.00
18333.30	-18.00	19333.30	-29.00	20000.00	-36.00
20833.30	-18.00	21000.00	-12.00	21333.30	-11.00
22000.00	-12.00	23333.30	-11.00	24166.60	-6.00
24333.30	0.00	24500.00	1.00	24666.60	0.00
25333.30	-4.00	26166.60	-6.00	27000.00	-11.00
27666.60	-6.00	28000.00	0.00	28333.30	1.00
28666.60	0.00	29333.30	-12.00	30333.30	-6.00
30666.60	-6.00	32000.00	-8.00	33000.00	-6.00
35500.00	-6.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts

10 37

E.2 Stations and Elevations

0.00	4.00	2666.70	0.00	3333.30	-0.50
4666.70	-4.00	6666.70	-7.00	9666.70	-5.00
12000.00	-6.00	12666.70	-10.00	13333.30	-6.00
14666.70	-4.00	16000.00	-7.00	17000.00	-6.00
17666.60	-10.00	18000.00	-6.00	18333.30	-1.00
18600.00	-6.00	18666.60	-12.00	18800.00	-18.00
19000.00	-24.00	19333.30	-52.00	20333.30	-40.00
21000.00	-22.00	21333.30	-18.00	21566.60	-12.00
22000.00	-10.00	22666.60	-12.00	23000.00	-16.00
23266.60	-12.00	23333.30	-6.00	23366.60	-0.50
23666.60	-0.50	24333.30	-1.00	25000.00	-6.00
25333.30	-6.00	25666.60	-0.50	27000.00	0.00
28333.30	4.00				

E.3 Mannings Coefficient at each station

0.1200	0.1200	0.1200	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.1200
0.1200	0.0250	0.0250	0.0250	0.1200	0.0250
0.0250					

E.1 Node Number of Elev Pts

11 25

E.2 Stations and Elevations

0.00	0.00	1166.70	-0.50	3333.30	-5.00
10000.00	-6.00	10333.30	-7.00	10666.70	-6.00
11500.00	-6.00	12000.00	-10.00	12500.00	-6.00
14166.70	-1.00	15333.30	-0.50	15666.70	-6.00
15866.70	-12.00	16066.70	-18.00	16666.70	-43.00
17333.30	-60.00	18333.30	-21.00	18800.00	-18.00
19066.60	-12.00	19200.00	-6.00	19233.30	-0.50
19500.00	-0.50	19666.60	-1.00	20000.00	-0.50
20333.30	0.00				

E.3 Mannings Coefficient at each station

0.1200	0.1200	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.1200	0.1200	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.1200	0.1200	0.1200	0.0250
0.0250					

E.1 Node Number of Elev Pts

12 21

E.2 Stations and Elevations

0.00	4.00	1500.00	0.00	2000.00	-0.50
3333.30	-4.00	5333.30	-4.00	6133.30	-0.50
7066.70	-0.50	7666.70	-2.00	8166.70	-6.00
8500.00	-12.00	8666.70	-18.00	9166.70	-20.00
10000.00	-53.00	10666.70	-68.00	12266.70	-24.00
12300.00	-18.00	12333.30	-12.00	12400.00	-6.00
12466.70	-0.50	12600.00	0.00	13000.00	4.00

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250			

E.1 Node Number of Elev Pts

13 16

E.2 Stations and Elevations

0.00	4.00	2600.00	0.00	2900.00	-0.50
3100.00	-6.00	3200.00	-12.00	3333.30	-18.00
5000.00	-33.00	6666.70	-42.00	7666.70	-36.00
8000.00	-24.00	8033.30	-18.00	8066.70	-12.00
8100.00	-6.00	8133.30	-0.50	8566.70	0.00
10000.00	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

14 16

E.2 Stations and Elevations

0.00	4.00	2600.00	0.00	2900.00	-0.50
3100.00	-6.00	3200.00	-12.00	3333.30	-18.00
5000.00	-33.00	6666.70	-42.00	7666.70	-36.00
8000.00	-24.00	8033.30	-18.00	8066.70	-12.00
8100.00	-6.00	8133.30	-0.50	8566.70	0.00
10000.00	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

15 20

E.2 Stations and Elevations

0.00	0.50	3333.30	0.50	4666.70	0.00
6266.70	-0.50	6333.30	-1.00	6833.30	-4.00
8333.30	-2.00	8933.30	-6.00	9333.30	-12.00
9900.00	-18.00	10000.00	-19.00	10433.30	-18.00
11066.70	-18.00	11666.70	-22.00	12200.00	-18.00
12400.00	-12.00	12833.30	-6.00	13066.70	-0.50
13333.30	0.00	13666.70	4.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

16 28

E.2 Stations and Elevations

0.00	0.50	1733.30	0.00	2166.70	-6.00
2266.70	-12.00	2300.00	-13.00	2333.30	0.00
3000.00	0.50	5666.70	0.00	5766.70	-0.50
6000.00	-22.00	6066.70	-0.50	7333.30	-0.50
8000.00	-2.00	8266.70	-6.00	8466.70	-12.00
8666.70	-18.00	10066.70	-18.00	10733.30	-12.00
10800.00	-6.00	10866.70	-0.50	11000.00	-6.00
11666.70	-10.00	12333.30	-6.00	13100.00	-0.50
13233.30	0.00	15000.00	0.50	17833.30	0.00
19666.60	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

17	20

E.2 Stations and Elevations

0.00	0.50	6900.00	0.00	7000.00	-0.50
7400.00	-6.00	7833.30	-12.00	8166.70	-18.00
8333.30	-18.00	8733.30	-12.00	9000.00	-7.00
9500.00	-12.00	9766.70	-12.00	10233.30	-6.00
10333.30	-5.00	11000.00	-3.00	11266.70	-6.00
11666.70	-10.00	12600.00	-6.00	13066.70	-0.50
13666.70	0.00	16666.70	2.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

18	33

E.2 Stations and Elevations

0.00	0.50	4500.00	0.50	4533.30	0.00
4566.70	-6.00	4600.00	-12.00	5500.00	-18.00
6000.00	-30.00	6500.00	-18.00	6666.70	-12.00
6733.30	-6.00	6833.30	-0.50	7066.70	0.00
7500.00	0.50	8166.70	0.00	8666.70	-0.50
9266.70	-6.00	9333.30	-12.00	9366.70	-18.00
9833.30	-20.00	10266.70	-18.00	10500.00	-12.00
10666.70	-6.00	11000.00	-0.50	11933.30	-0.50
12066.70	-6.00	12333.30	-10.00	12500.00	-12.00
13166.70	-12.00	13733.30	-6.00	14066.70	-0.50
14500.00	0.00	17333.30	0.50	17533.30	4.00

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250			

E.1 Node Number of Elev Pts

19 38

E.2 Stations and Elevations

0.00	0.50	2333.30	0.00	2666.70	-3.00
2800.00	-3.00	2866.70	0.00	4000.00	0.50
4066.70	4.00	4133.30	0.50	6000.00	0.00
6200.00	-12.00	6266.70	-18.00	6400.00	-20.00
6533.30	-18.00	6800.00	0.00	7000.00	0.50
7133.30	0.00	7166.70	-6.00	7333.30	-9.00
7666.70	-6.00	7833.30	0.00	8000.00	0.50
9666.70	0.50	9833.30	0.00	10000.00	-18.00
10333.30	-26.00	10733.30	-12.00	11000.00	-0.50
11600.00	0.00	12500.00	0.50	13066.70	0.00
13200.00	-0.50	14000.00	-12.00	14333.30	-14.00
14500.00	-12.00	15066.70	-0.50	15266.70	0.00
23666.60	0.50	25000.00	4.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

20 38

E.2 Stations and Elevations

0.00	0.50	1000.00	0.50	1166.70	0.00
1266.70	-6.00	1666.70	-7.00	1933.30	-6.00
2066.70	0.00	3333.30	0.50	6666.70	0.00
7333.30	0.00	7400.00	-6.00	7666.70	0.00
8000.00	-38.00	8266.70	0.00	10000.00	0.50
11000.00	0.50	11200.00	4.00	11600.00	0.50
12166.70	0.00	12333.30	-0.50	12400.00	-6.00
12533.30	-12.00	12733.30	-18.00	13333.30	-23.00
13533.30	-18.00	13733.30	-0.50	13833.30	0.00
15000.00	0.50	16066.70	0.50	16100.00	0.00
16133.30	-6.00	16800.00	-12.00	17066.60	-14.00
17266.60	-12.00	17466.60	-6.00	17833.30	-0.50
20000.00	0.50	23666.60	4.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

21 33

E.2 Stations and Elevations

9.00	0.50	666.70	0.50	733.30	0.00
833.30	-6.00	1166.70	-9.00	1466.70	-6.00
1633.30	0.00	1666.70	0.50	8000.00	0.50
8166.70	0.00	8266.70	-6.00	8400.00	-20.00
8533.30	0.00	8666.70	0.50	12400.00	0.50
12433.30	0.00	12600.00	-6.00	12733.30	-12.00
13166.70	-15.00	13333.30	-15.00	13600.00	-6.00
13700.00	0.00	13733.30	0.50	16500.00	0.50
16533.30	0.00	16666.70	-0.50	16866.60	-12.00
17133.30	-18.00	17333.30	-30.00	17666.60	-18.00
17866.60	0.00	17900.00	0.50	19000.00	4.00

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250			

E.1 Node Number of Elev Pts

22 26

E.2 Stations and Elevations

0.00	0.50	1666.70	0.50	1700.00	0.00
1800.00	-6.00	2166.70	-11.00	2400.00	-6.00
2600.00	0.00	2666.70	0.50	5800.00	0.50
5833.30	0.00	5933.30	-5.00	5966.70	0.00
6000.00	0.50	11600.00	0.50	11633.30	0.00
11733.30	-6.00	12066.70	-12.00	12500.00	-17.00
12900.00	-12.00	13333.30	-10.00	14000.00	-12.00
14266.70	-6.00	14666.70	-0.50	14866.70	0.00
15000.00	0.50	21000.00	4.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

23	31

E.2 Stations and Elevations

0.00	0.50	3133.30	0.50	3166.70	0.00
3266.70	-5.00	3333.30	-12.00	4333.30	-12.00
4666.70	0.00	4733.30	0.50	9266.70	0.50
9300.00	0.00	9400.00	-0.50	9600.00	-12.00
9733.30	-18.00	10000.00	-35.00	10333.30	-18.00
10466.70	-12.00	10600.00	0.00	10666.70	0.50
13600.00	0.50	13666.70	0.00	14166.70	-12.00
14933.00	0.00	15000.00	0.50	15500.00	0.50
15533.30	0.00	15666.70	-6.00	15866.70	-13.00
16233.30	-0.50	16333.30	0.00	16400.00	0.50
25166.60	0.50				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts

24	31

E.2 Stations and Elevations

0.00	0.50	3133.30	0.50	3166.70	0.00
3266.70	-5.00	3333.30	-12.00	4333.30	-12.00
4666.70	0.00	4733.30	0.50	9266.70	0.50
9300.00	0.00	9400.00	-0.50	9600.00	-12.00
9733.30	-18.00	10000.00	-35.00	10333.30	-18.00
10466.70	-12.00	10600.00	0.00	10666.70	0.50
13600.00	0.50	13666.70	0.00	14166.70	-12.00
14933.00	0.00	15000.00	0.50	15500.00	0.50
15533.30	0.00	15666.70	-6.00	15866.70	-13.00
16233.30	-0.50	16333.30	0.00	16400.00	0.50
25166.60	0.50				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts

25	16

E.2 Stations and Elevations

0.00	4.00	2600.00	0.00	2900.00	-0.50
3100.00	-6.00	3200.00	-12.00	3333.30	-18.00
5000.00	-33.00	6666.70	-42.00	7666.70	-36.00
8000.00	-24.00	8033.30	-18.00	8066.70	-12.00
8100.00	-6.00	8133.30	-0.50	8566.70	0.00
10000.00	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

26 28

E.2 Stations and Elevations

0.00	4.00	2266.70	0.00	2433.30	-0.50
2600.00	-42.00	3333.30	-48.00	4500.00	-27.00
4600.00	-18.00	4666.70	-12.00	4833.30	-6.00
5666.70	-12.00	6000.00	-12.00	6600.00	-6.00
6733.30	-6.00	7000.00	-8.00	7800.00	-12.00
8000.00	-17.00	8333.30	-12.00	8433.30	-6.00
9200.00	-0.50	10400.00	0.00	10500.00	0.50
13833.30	0.50	13866.70	0.00	14000.00	-6.00
14166.70	-7.00	14500.00	-6.00	14666.70	0.00
14733.30	0.50				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

27 26

E.2 Stations and Elevations

0.00	4.00	1933.30	0.50	4500.00	0.50
4533.30	0.00	4700.00	-0.50	5166.70	-6.00
5366.70	-12.00	5466.70	-18.00	5666.70	-22.00
6666.70	-30.00	8166.70	-24.00	8666.70	-18.00
8800.00	-6.00	9066.70	-0.50	9300.00	-0.50
9333.30	-1.00	10500.00	-6.00	11666.70	-13.00
12066.70	-6.00	12566.70	-0.50	12666.70	0.00
13000.00	0.50	13066.70	-9.00	13133.30	0.00
13333.30	0.50	23333.30	0.50		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

28 26

E.2 Stations and Elevations

0.00	0.50	6300.00	0.50	6333.30	0.00
6666.70	-20.00	6933.30	0.00	7000.00	0.50
8266.70	0.50	8333.30	0.00	8400.00	-0.50
9166.70	-20.00	10000.00	-20.00	10400.00	-18.00
11733.30	-18.00	12333.30	-21.00	13333.30	-32.00
13933.30	-18.00	14200.00	-12.00	14400.00	-6.00
14666.70	-5.00	14866.70	-6.00	15333.30	-19.00
15866.70	-6.00	16433.30	-0.50	16666.70	0.00
17333.30	0.50	20000.00	0.50		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

29 31

E.2 Stations and Elevations

0.00	0.50	3866.70	0.50	3933.30	0.00
4166.70	-6.00	4266.70	0.00	4333.30	0.50
5933.30	0.50	6000.00	0.00	7000.00	-0.50
8933.30	-6.00	9600.00	-6.00	10000.00	-12.00
10333.30	-14.00	10933.30	-12.00	11166.70	-10.00
12033.30	-12.00	13000.00	-24.00	13333.30	-32.00
13666.70	-25.00	14600.00	-18.00	14633.00	-12.00
15266.70	-12.00	15666.70	-0.50	15933.30	0.00
16000.00	0.50	16600.00	0.50	16666.70	0.00
18400.00	-9.00	18500.00	0.00	18666.60	0.50
20000.00	0.50				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts
30 23
E.2 Stations and Elevations

0.00	0.50	2166.70	0.50	2500.00	4.00
2800.00	0.50	7000.00	0.50	7166.70	0.00
7600.00	-0.50	8333.30	-3.00	10000.00	-6.00
10400.00	-12.00	10666.70	-19.00	11733.30	-18.00
12333.30	-25.00	13166.70	-27.00	13333.30	-32.00
13600.00	-23.00	14000.00	-18.00	14166.70	-12.00
14333.30	-6.00	14400.00	-0.50	14833.30	0.00
14933.30	0.50	20000.00	0.50		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	

E.1 Node Number of Elev Pts
31 21
E.2 Stations and Elevations

0.00	0.50	666.70	4.00	1066.70	0.50
4000.00	0.50	4033.30	0.00	4166.70	-13.00
4400.00	0.00	4433.30	0.50	4933.30	0.50
5000.00	0.00	6133.30	-6.00	6333.30	-12.00
6666.70	-18.00	8133.30	-25.00	8333.30	-32.00
8600.00	-23.00	9200.00	-18.00	9266.70	0.00
9500.00	2.00	9733.30	0.50	16666.70	0.50

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250			

E.1 Node Number of Elev Pts
32 23
E.2 Stations and Elevations

0.00	0.50	533.30	4.00	1066.70	0.50
4533.30	0.50	5133.30	-6.00	5200.00	-12.00
5533.30	-18.00	6466.70	-21.00	6666.70	-32.00
6933.30	-22.00	7500.00	-20.00	7866.70	-18.00
8133.30	-6.00	8733.30	-0.50	8833.30	0.00
9166.70	2.00	9400.00	0.50	9666.70	0.50
9700.00	0.00	9733.30	-1.50	9800.00	0.00
9833.30	0.50	16666.70	0.50		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	

E.1 Node Number of Elev Pts

33 25

E.2 Stations and Elevations

38000.00	0.00	38060.00	-27.00	38072.00	-32.00
38260.00	-29.00	38272.00	-29.00	38361.00	-32.00
38373.00	-32.00	38511.00	-30.00	38523.00	-30.00
38662.00	-33.00	38675.00	-33.00	38956.00	-37.00
38968.00	-37.00	39137.00	-38.00	39149.00	-38.00
39287.00	-35.00	39299.00	-35.00	39439.00	-32.00
39451.00	-32.00	39588.00	-32.00	39600.00	-32.00
39740.00	-23.00	40347.00	-20.00	40562.00	-23.00
40776.00	-2.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts

34 45

E.2 Stations and Elevations

38000.00	0.00	38060.00	-27.00	38061.00	20.00
38071.00	20.00	38072.00	-27.00	38260.00	-26.00
38261.00	20.00	38271.00	20.00	38272.00	-26.00
38361.00	-30.00	38362.00	20.00	38372.00	20.00
38373.00	-30.00	38511.00	-28.00	38512.00	20.00
38522.00	20.00	38523.00	-28.00	38662.00	-33.00
38663.00	20.00	38673.00	20.00	38674.00	-33.00
38956.00	-35.00	38957.00	20.00	38967.00	20.00
38968.00	-35.00	39137.00	-35.00	39138.00	20.00
39148.00	20.00	39149.00	-35.00	39287.00	-36.00
39288.00	20.00	39298.00	20.00	39299.00	-36.00
39439.00	-31.00	39440.00	20.00	39450.00	20.00
39451.00	-31.00	39588.00	-30.00	39589.00	20.00
39599.00	20.00	39600.00	-30.00	39740.00	-27.00
40347.00	-22.00	40562.00	-20.00	40776.00	-2.00

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250			

E.1 Node Number of Elev Pts

35 45

E.2 Stations and Elevations

38000.00	0.00	38060.00	-27.00	38061.00	20.00
38071.00	20.00	38072.00	-32.00	38260.00	-29.00
38261.00	20.00	38271.00	20.00	38272.00	-29.00
38361.00	-32.00	38362.00	20.00	38372.00	20.00
38373.00	-32.00	38511.00	-30.00	38512.00	20.00
38522.00	20.00	38523.00	-30.00	38662.00	-33.00
38663.00	20.00	38673.00	20.00	38675.00	-33.00
38956.00	-37.00	38957.00	20.00	38967.00	20.00
38968.00	-37.00	39137.00	-38.00	39138.00	20.00
39148.00	20.00	39149.00	-38.00	39287.00	-35.00
39288.00	20.00	39298.00	20.00	39299.00	-35.00
39439.00	-32.00	39440.00	20.00	39450.00	20.00
39451.00	-32.00	39588.00	-32.00	39589.00	20.00
39599.00	20.00	39600.00	-32.00	39740.00	-32.00
40347.00	-23.00	40562.00	-20.00	40776.00	-23.00

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250			

E.1 Node Number of Elev Pts

36	24

E.2 Stations and Elevations

38000.00	0.00	38060.00	-30.00	38072.00	-30.00
38260.00	-30.00	38272.00	-30.00	38361.00	-31.00
38373.00	-31.00	38511.00	-33.00		
38523.00	-33.00	38662.00	-29.00	38675.00	-29.00
38956.00	-34.00	38968.00	-34.00	39137.00	-35.00
39149.00	-35.00	39287.00	-33.00	39299.00	-33.00
39439.00	-29.00	39451.00	-29.00	39588.00	-28.00
39600.00	-28.00	39740.00	-23.00	40347.00	-22.00
40562.00	-2.0				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250

E.1 Node Number of Elev Pts

37	16

E.2 Stations and Elevations

0.00	4.00	200.00	0.50	2200.00	0.50
2233.30	0.00	3833.30	-6.00	3933.30	-12.00
4066.70	-18.00	4833.30	-21.00	5000.00	-32.00
5400.00	-26.00	6100.00	-18.00	6333.30	-17.00
6666.00	-12.00	7133.30	-6.00	7433.30	0.00
7666.70	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

38 26

E.2 Stations and Elevations

0.00	0.50	1000.00	0.50	1233.30	4.00
1333.30	0.50	4966.70	0.50	5000.00	0.00
5066.70	-6.00	5200.00	-12.00	5933.30	-18.00
6466.70	-19.00	6666.70	-32.00	6800.30	-21.00
7466.70	-18.00	7533.30	-12.00	7566.70	-6.00
7733.30	0.00	7933.30	-6.00	7966.70	-12.00
8166.70	-18.00	8333.30	-21.00	8466.70	-18.00
9066.00	-12.00	9333.30	-18.00	9666.70	-27.00
11000.70	-18.00	11033.00	4.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

39 25

E.2 Stations and Elevations

0.00	1.00	600.00	4.00	833.30	0.50
4933.30	0.50	5000.00	0.00	5066.70	-6.00
5133.30	-12.00	5600.00	-18.00	6466.70	-25.00
6666.70	-32.00	6800.00	-29.00	7466.70	-18.00
7666.70	-12.00	7833.30	-6.00	7966.70	-0.50
8533.30	0.00	9000.00	4.00	14333.30	4.00
15333.30	0.00	15366.70	-12.00	15400.00	-18.00
15666.70	-27.00	15700.00	-14.00	15866.70	0.00
17333.30	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts

40	22

E.2 Stations and Elevations

0.00	4.00	1066.70	0.50	6000.00	0.50
6033.30	0.00	6166.70	-6.00	6266.70	-12.00
6500.00	-22.00	6666.70	-32.00	6933.30	-31.00
8100.00	-18.00	8300.00	-12.00	8333.30	-6.00
8366.70	-0.50	8433.30	0.00	9000.00	4.00
5166.70	4.00	15900.00	0.00	15933.30	-25.00
16166.70	-27.00	16400.00	-25.00	16633.30	0.00
16666.70	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

41	37

E.2 Stations and Elevations

0.00	0.50	1000.00	0.50	1666.70	0.00
2166.70	-3.00	2333.30	0.00	2366.70	0.50
4600.00	0.50	4666.70	0.00	5000.00	-2.00
5500.00	-0.50	5866.70	-6.00	5933.30	-12.00
6200.00	-18.00	6266.70	-20.00	6333.30	-18.00
6366.70	0.00	6400.00	0.50	9066.70	0.50
9266.70	-0.50	9333.30	-6.00	9833.30	-20.00
10000.00	-32.00	10233.30	-22.00	11333.30	-18.00
11566.70	-12.00	11666.70	-6.00	11800.00	-0.50
12066.70	-0.50	13000.00	-3.00	13666.70	-1.00
15833.30	0.00	16000.00	0.50	19666.60	0.50
19700.00	0.00	19833.30	-20.00	20166.60	0.00
20333.30	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts

42	38

E.2 Stations and Elevations

0.00	0.50	2733.30	0.50	2766.70	0.00
3000.00	-9.00	3133.30	0.00	3166.70	0.50
5666.70	0.50	5700.00	0.00	5833.30	-6.00
5933.30	-18.00	6000.00	-6.00	6066.70	0.00
7533.30	0.50	7900.00	4.00	13600.00	0.50
14400.00	-0.50	15000.00	-12.00	15266.70	-16.00
15400.00	-12.00	15733.30	-6.00	15833.30	-2.00
15933.30	-6.00	16266.70	-18.00	16500.00	-21.00
16666.70	-32.00	16833.30	-21.00	17400.00	-18.00
17500.00	0.00	17533.30	0.50	21533.30	0.00
21666.60	-6.00	21900.00	0.00	21933.30	0.50
22866.60	0.00	23200.00	-6.00	23266.60	0.00
23333.30	0.50	23666.60	4.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

43	38

E.2 Stations and Elevations

0.00	0.50	2733.30	0.50	2766.70	0.00
3000.00	-9.00	3133.30	0.00	3166.70	0.50
5666.70	0.50	5700.00	0.00	5833.30	-6.00
5933.30	-18.00	6000.00	-6.00	6066.70	0.00
7533.30	0.50	7900.00	4.00	13600.00	0.50
14400.00	-0.50	15000.00	-12.00	15266.70	-16.00
15400.00	-12.00	15733.30	-6.00	15833.30	-2.00
15933.30	-6.00	16266.70	-18.00	16500.00	-21.00
16666.70	-32.00	16833.30	-21.00	17400.00	-18.00
17500.00	0.00	17533.30	0.50	21533.30	0.00
21666.60	-6.00	21900.00	0.00	21933.30	0.50
22866.60	0.00	23200.00	-6.00	23266.60	0.00
23333.30	0.50	23666.60	4.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

Appendix C
EXTER.DAT File

****

F Time-Dependent Data

****

F.1 Index	Time	Node 1	Node 25	Node 43
1	5.00	5.00	0.00	0.00
2	5.50	5.80	0.00	0.00
3	6.00	7.00	0.00	0.00
4	6.50	7.50	0.00	0.00
5	7.00	8.00	0.00	0.00
6	7.50	8.50	0.00	0.00
7	8.00	8.75	0.00	0.00
8	8.50	8.80	0.00	0.00
9	9.00	9.00	0.00	0.00
10	9.50	8.75	0.00	0.00
11	10.00	8.00	0.00	0.00
12	10.50	7.50	0.00	0.00
13	11.00	6.00	0.00	0.00
14	12.50	3.50	0.00	0.00
15	13.50	1.50	0.00	0.00
16	14.00	0.20	0.00	0.00
17	14.50	0.15	0.00	0.00
18	15.00	0.10	0.00	0.00
19	15.50	0.15	0.00	0.00
20	16.00	1.50	0.00	0.00
21	17.50	4.50	0.00	0.00
22	18.00	6.00	0.00	0.00
23	18.50	7.00	0.00	0.00
24	19.00	8.00	0.00	0.00
25	19.50	8.50	0.00	0.00
26	20.00	8.75	0.00	0.00
27	20.50	8.80	0.00	0.00
28	21.00	9.00	0.00	0.00
29	21.50	8.75	0.00	0.00
30	22.00	8.00	0.00	0.00
32	22.50	7.50	0.00	0.00

33	23.00	6.00	0.00	0.00
34	24.50	3.50	0.00	0.00
35	25.50	1.50	0.00	0.00

Appendix D
PARAM.DAT File

PARAM.DAT Input Data File for DYNLET Graphs

G.1 Number of Nodes at which velocity plots are desired:
1
G.2 Node Number for Velocity Plot:
35
G.3 Number of Velocity Stations at this Node =
4
G.4 The Velocity Stations are:
11 12 13 14
H.1 Number of Nodes for Stage Graphs =
13
H.2 The Stage Graph Nodes are:
1 2 3 4 5 6 22 23
33 34 35 36 38

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13. ABSTRACT *(Maximum 200 words)*

A state-of-the-art design-level model for predicting tide-dominated velocities and water level fluctuations at an inlet and interior back-bay system and detailed instruction in use of the model are presented. The model solves the full one-dimensional (1-D) shallow-water equations employing an implicit finite-difference technique. The model is named DYNLET1, reflecting the fact that it is a 1-D model of the dynamic (time-dependent) behavior of the tidal flow at inlets.

The DYNLET1 numerical model was originally developed by Dr. Michael Amein, Civil Analysis Group, Inc., Raleigh, North Carolina, under contract to the U.S. Army Engineer Waterways Experiment Station (WES) Coastal Engineering Research Center (CERC). The model is capable of simulating 1-D fluid flow from the ocean through a tidal inlet, into back-bay regions, and up tributaries. An important feature of the model is the ability to represent an accurate flow distribution across any cross section, given the inherent limitations of a 1-D model.

DYNLET1 has a rigorous theoretical foundation, is numerically implemented in a sound manner, and is capable of describing realistic situations. It provides detailed velocity information across the inlet channels, is able to describe multi-channel inlets, and importantly, is easy to operate on a personal computer. The model can be used for design-level studies for most inlets by providing reliable and accurate answers while requiring minimal modeling expertise, data entry, and numerical grid generation.

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